Fishery Data Series No. 18-35

Kanalku Lake Subsistence Sockeye Project: 2017 Annual Report and 2014–2017 Final Report

by

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and

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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

The sockeye salmon (*Oncorhynchus nerka*) run at Kanalku Lake, Southeast Alaska, is the preferred traditional sockeye salmon subsistence stock for the nearby community of Angoon. A stock assessment program was initiated at Kanalku Lake in 2001 in response to community concerns over declining run size and possible overexploitation by local fishermen. Annual spawning escapements were estimated through mark–recapture studies from 2001 to 2006, through a standard picket weir from 2007 to 2014, and through a camera weir from 2015 to 2017. We counted a spawning escapement of 468 sockeye salmon through a double-fence camera weir at the outflow of Kanalku Lake in 2017—the third lowest spawning escapement since stock assessment began in 2001. We also operated a camera weir downstream of Kanalku Falls to estimate the total escapement into the Kanalku system and to estimate the inriver mortality associated with the partial barrier falls. The total escapement into the Kanalku system was 870 sockeye salmon; thus 54% of the inriver run successfully ascended the falls in 2017, an inriver mortality rate of 46%. Sockeye salmon passage rates have not markedly improved since barrier modification work was conducted at the falls in 2013. Inriver passage rates averaged 63% from 2014 to 2017 and ranged from 54% (2017) to 72% (2016); very similar to the passage rates of 49% (2012) and 76% (2013) observed before the barrier modification work was completed. The Kanalku Lake sockeye salmon run has been limited by very small spawning escapements that have produced modest numbers of adult recruits 4–5 years later. Spawning escapements will need to increase substantially if annual runs are expected to improve above the low levels observed since 2001.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, escapement, weir, mark–recapture, age composition, Southeast Alaska, video camera

INTRODUCTION

Kanalku Lake, located on the western side of Admiralty Island, supports a small run of sockeye salmon (*Oncorhynchus nerka*) that provides the primary sockeye salmon subsistence resource for the nearby community of Angoon (Bednarski et al. 2014). The use of Kanalku Bay as a traditional subsistence fishery has been documented in several historical and archaeological records, and artifacts from a traditional salmon weir at the head of Kanalku Bay provides physical evidence of the exploitation of salmon resources for at least the last 1,000 years (de Laguna 1960; Moss 1989; Thornton et al. 1990; Goldschmidt and Haas 1998). Other sockeye salmon runs in the vicinity, including Sitkoh and Basket bays, also provide subsistence opportunity for Angoon residents, but access to those locations from Angoon requires travel by boat across the open waters of Chatham Strait; thus, Kanalku Bay remains the preferred harvest area due to its close proximity to the village and ease of access through sheltered waterways (Geiger et al. 2007).

The introduction of the commercial fishing industry in Southeast Alaska greatly influenced the lives of Native families since the early 20th century. New federal fishing laws and Alaska Native participation in the commercial fishing industry led to changes in traditional fishing practices among the Natives of Angoon and other Southeast Alaska villages (Thornton et al. 1990; Betts and Wolfe 1992; Turek et al. 2006). After the adoption of Alaska statehood, a non-commercial subsistence fishery was defined and placed under a permit system (Turek et al. 2006). Participation in commercial fisheries by Angoon residents has declined steadily since the 1980s: in 1980, 90 residents fished 134 commercial fisheries permits; however, by 2010, only six residents fished six commercial permits (Bednarski et al. 2014). This decline in participation in commercial fisheries has led to a loss in mobility, which has concentrated the community's subsistence activities closer to home (Bednarski et al. 2014). Residents of Angoon can obtain subsistence fishing permits for Kanalku and other nearby areas, but most people prefer to fish in Kanalku Bay (Conitz and Burril 2008). From 1985 to 2001, Kanalku Bay accounted for an average 85% of the reported sockeye salmon subsistence harvest by Angoon residents, and the reported annual harvest and participation at Kanalku increased substantially from a 1985–1992 average of 580 fish and 24 permits to a 1993–2001 average of 1,300 fish and 58 permits (Figure 1; Bednarski et al. 2014).

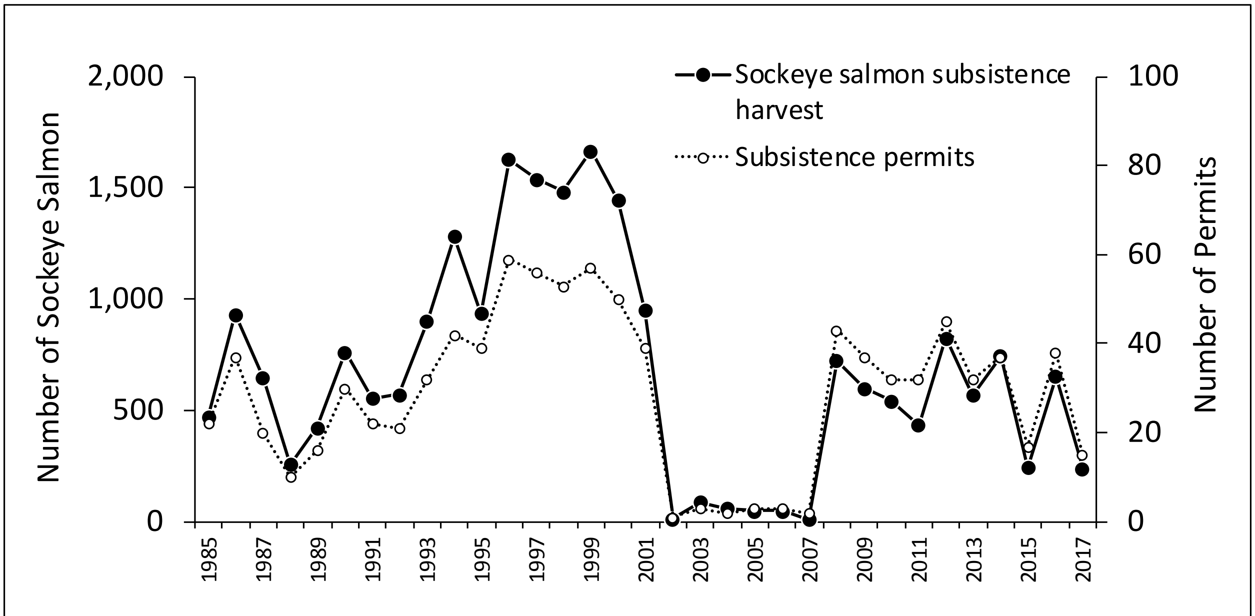

Figure 1.–Kanalku sockeye salmon subsistence harvest reported on returned ADF&G permits, 1985–2017.

In 2001, the Alaska Department of Fish and Game (ADF&G), the Angoon Community Association (ACA), and the USDA Forest Service (USFS) initiated a stock assessment program at Kanalku Lake to address concerns regarding increased harvest, possible decline in run size, and lack of information about spawning escapements (Conitz and Cartwright 2005). This project was approved through the U.S. Fish and Wildlife Service Office of Subsistence Management and funded and administered by the USFS. From 2001 to 2006, mark–recapture studies were conducted at Kanalku Lake to estimate the spawning population of sockeye salmon (Conitz and Burrill 2008). In 2007, ADF&G and the ACA improved the stock assessment project by operating a salmon counting weir directly below the outlet of Kanalku Lake and conducting mark–recapture studies to verify weir counts (Appendix A; Vinzant et al. 2009). In 2014 a secondary video camera weir was installed upstream of the standard picket weir to verify fish counts—rather than a mark–recapture study—to reduce fish handling at the weir site and on the spawning grounds (Vinzant and Heinl 2015a). During the 2016 season, this system was replaced with a double-fenced video weir to count the spawning escapement of sockeye salmon. This method provided a complete census of the spawning escapement while allowing fish to freely pass unimpeded into the lake 24 hours per day (Vinzant and Heinl 2017).

In 2001, the reported subsistence harvest of 951 sockeye salmon far exceeded a mark–recapture estimate of only 250 spawners at Kanalku Lake (Conitz and Cartwright 2005). In an effort to rebuild the run, ADF&G and the community of Angoon instituted a voluntary subsistence harvest closure at Kanalku from 2002 to 2005. In addition, ADF&G liberalized annual harvest limits at other traditionally used systems near Angoon to provide opportunity for Angoon residents to fulfill subsistence needs (Conitz and Burril 2008; Bednarski et al. 2014). During the voluntary closure years (2002–2005), the reported Kanalku subsistence harvest averaged 50 fish

(Figure 1) and spawning escapements averaged 1,060 fish. In 2006, the department and the community agreed to end the voluntary closure at Kanalku; however, the annual limit at Kanalku was reduced from 25 to 15 fish per household to allow for a conservative harvest and to continue rebuilding the run (Bednarski et al. 2014). Since 2008, the reported Kanalku subsistence harvest has averaged 590 fish and spawning escapements improved to an average 1,660 fish.

In addition to concerns regarding increased subsistence harvest and small escapements, there are concerns regarding the negative impact the partial barrier falls on Kanalku Creek has on the total size of the sockeye salmon spawning population. After swimming upstream from saltwater, sockeye salmon sit in pools below the falls for variable lengths of time, depending on water flow, where they are subjected to high rates of predation and additional physical stress as they repeatedly attempt to scale the falls and migrate upstream. In 1970, the USFS and ADF&G blasted four shallow step pools on the apron on the left side of Kanalku Falls to improve fish passage (Geiger et al. 2007; USDAFS 2011). The effect on fish passage is not known, however, since no pre- or post-modification studies were conducted, and many fish still do not successfully ascend the falls. The cooperative stock assessment program initiated at Kanalku in 2001 provided estimates of the spawning population at the lake, but not the total number of fish that enter the Kanalku system, or the number that fail to make it over the falls. Incomplete studies conducted in 2008 and 2009 suggested that a large portion of the sockeye salmon escapement did not migrate past the falls in those years (USDAFS 2011), but those studies did not provide precise estimates of the total sockeye salmon escapement into the Kanalku system (Vinzant and Bednarski 2010).

In 2012, ADF&G initiated a study to quantify the inriver mortality of sockeye salmon incurred at Kanalku Falls. This project was subsequently funded through grants from the Alaska Sustainable Salmon Fund. Camera weirs, equipped with motion-detection digital video recorders (DVR) and underwater cameras, were used to count the total sockeye salmon escapement into lower Kanalku Creek below Kanalku Falls. The inriver mortality was determined by simply subtracting the spawning escapement (the number of fish counted at the lake) from the total escapement (the number of fish counted below the falls). On 28 August 2013, the USFS and ADF&G conducted Phase I of a two-phase project (USDAFS 2011) to further modify the Kanalku Falls and improve sockeye salmon passage. A large shelf of bedrock, approximately 12–15 cubic yards of material, was blasted out of the plunge-pool at the base of Kanalku Falls to widen and deepen the pool and provide sockeye salmon a better jump at the falls (Greg Albrecht, Habitat Biologist, ADF&G, Douglas; memorandum 24 September 2013). Prior to modification of the falls, inriver sockeye salmon passage rates were estimated to be 49% in 2012 and 76% in 2013. Following the falls modification, the inriver passage rates were estimated to be 65% in 2014, 62% in 2015, and 72% in 2016 (Vinzant et al. 2013; Vinzant and Heinl 2014, 2015a, 2016, and 2017).

Commercial harvest of Kanalku-bound sockeye salmon occurs in mixed stock purse seine fisheries that target pink salmon (*O. gorbuscha*) in Chatham and Icy straits, although the contribution is assumed to be very low (Geiger et al. 2007). The timing of commercial purse seine fishery openings and their distance from Kanalku Bay are managed to minimize incidental harvest of Kanalku fish. Subsistence harvest data indicates most (80%) of the Kanalku Bay subsistence harvest occurs prior to the average first date of the commercial purse seine opening in statistical area 112-16, where the majority (65%) of sockeye salmon harvest in this fishery takes place (Bednarski et al. 2014). ADF&G conducted a study from 2012 to 2014 to better understand the contribution, run timing, and distribution of Northern Chatham Strait sockeye salmon stocks harvested in these fisheries using genetic mixed stock analysis. In 2012 and 2014, small Chatham Strait sockeye salmon stocks were combined into one reporting group and were estimated to have contributed fewer than 300 fish to the commercial fisheries that were sampled—of which the Kanalku stock would have contributed a very small portion. In 2013, a year with some of the most extensive purse seine fishing on record (Gray et al. 2014), Kanalku fish accounted for an estimated 0.5% of the sockeye salmon harvested (fewer than 300 fish) in the fisheries sampled (Gilk-Baumer et al. 2015). Approximately nine nautical miles along the eastern shore of Chatham Strait between Parker Point and Point Samuel has been closed to the purse seine fishery since 1999 to conserve Kanalku sockeye salmon. This area, which encompasses the community of Angoon, Kootznahoo Inlet, and the entrance to Kanalku Bay, was added to the list of closed waters in state regulation (5AAC 33.350(m)(10)) at the Alaska Board of Fisheries meeting in 2015. Additional time and area closures were also put into regulation along the Admiralty shore north of Parker Point (5AAC 33.366 (c)(1 and 2)) to conserve Kanalku sockeye salmon.

In 2017, we conducted the 17th and final year of stock assessment work to estimate the sockeye salmon spawning escapement at Kanalku Lake, and for the sixth consecutive year we estimated the inriver mortality associated with Kanalku Falls—a significant source of mortality on the run and a key aspect of the stock's life history. This information, along with biological data on age and size at return, will directly benefit management of the Kanalku subsistence fishery through more complete accounting of sockeye salmon production by brood year and improved expectations of annual run size. Information collected on the inriver mortality rate associated with fish passage over Kanalku Falls will help to assess the success of the recent barrier modification work and determine if further alteration will be required to improve fish passage.

OBJECTIVES

1. Count all salmon species that enter lower Kanalku Creek, below Kanalku Falls, through a camera weir for the duration of the sockeye salmon run to estimate total escapement into the Kanalku system.
2. Count all salmon species passed through a camera weir into Kanalku Lake, upstream of Kanalku Falls, for the duration of the sockeye salmon run to estimate spawning escapement.
3. Estimate the sockeye salmon mortality rate at Kanalku Falls.
4. Estimate the age, length, and sex composition of the Kanalku Lake sockeye salmon spawning escapement such that the estimated proportion of each age class is within 5% of the true value with at least 90% probability.

METHODS

STUDY SITE

Kanalku Lake (lat 57º 29.22′N, long 134º 21.02′W) is located about 20 km southeast of Angoon (Figure 2) and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). The U-shaped valley and rounded mountainsides are characterized by underlying carbonate bedrock and built up soil layers supporting a highly productive spruce forest, especially over major colluvial and alluvial fans (Nowacki et al. 2001). The watershed area is approximately 32 km^2, with one major inlet stream (ADF&G stream no. 112-67-060) draining into the east end of the lake. The lake elevation is approximately 28 m. The lake surface area is approximately 113 hectares, with mean depth of 15 m, and maximum depth of 22 m (Figure 3). The outlet stream, Kanalku Creek (ADF&G stream no. 112-67-058), is 1.7 km long and drains into the east end of Kanalku Bay. In addition to sockeye salmon spawning in the lake, large numbers of pink salmon spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum (*O. keta*) salmon spawn in the Kanalku system, and resident populations of cutthroat trout (*O. clarkii*), Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus sp.*) are found in Kanalku Lake. Kanalku Falls, a waterfall approximately 8–10 m high and about 0.8 km upstream from the tidewater, forms a partial barrier to migrating sockeye salmon.

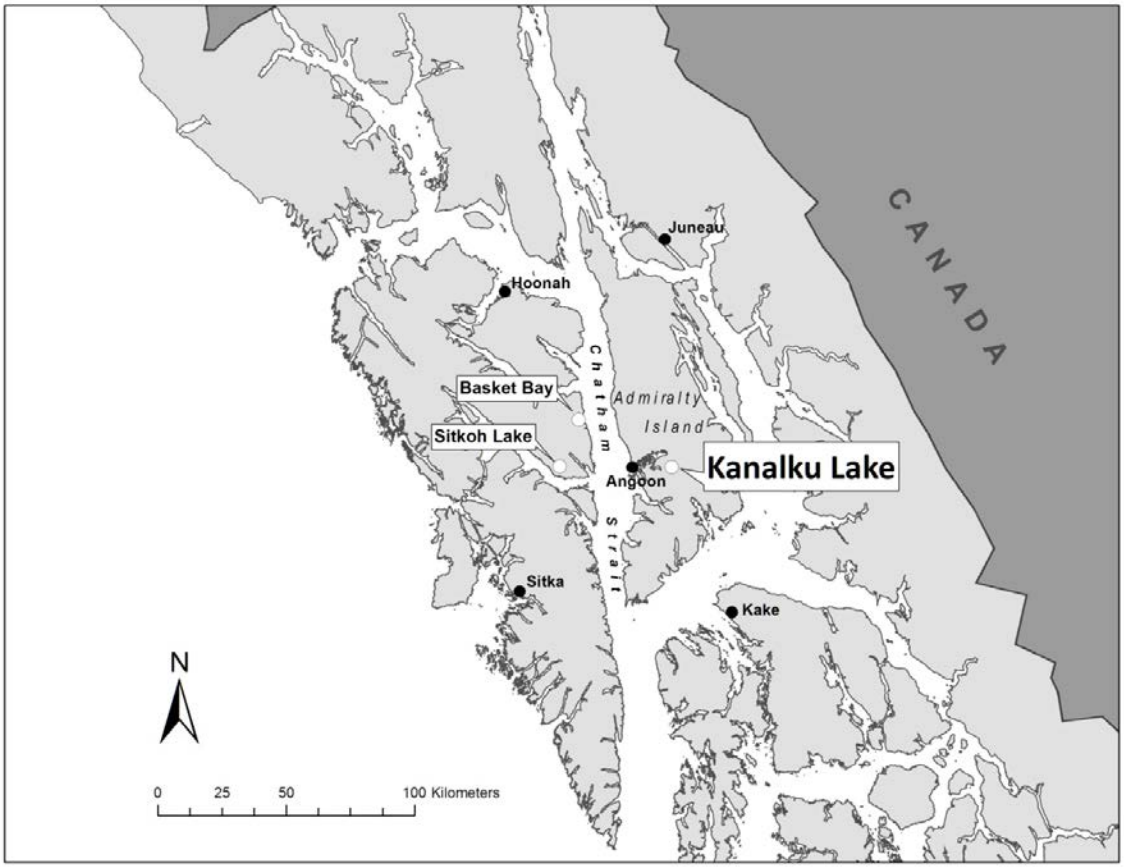

Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake, the village of Angoon, and other locations mentioned in the text.

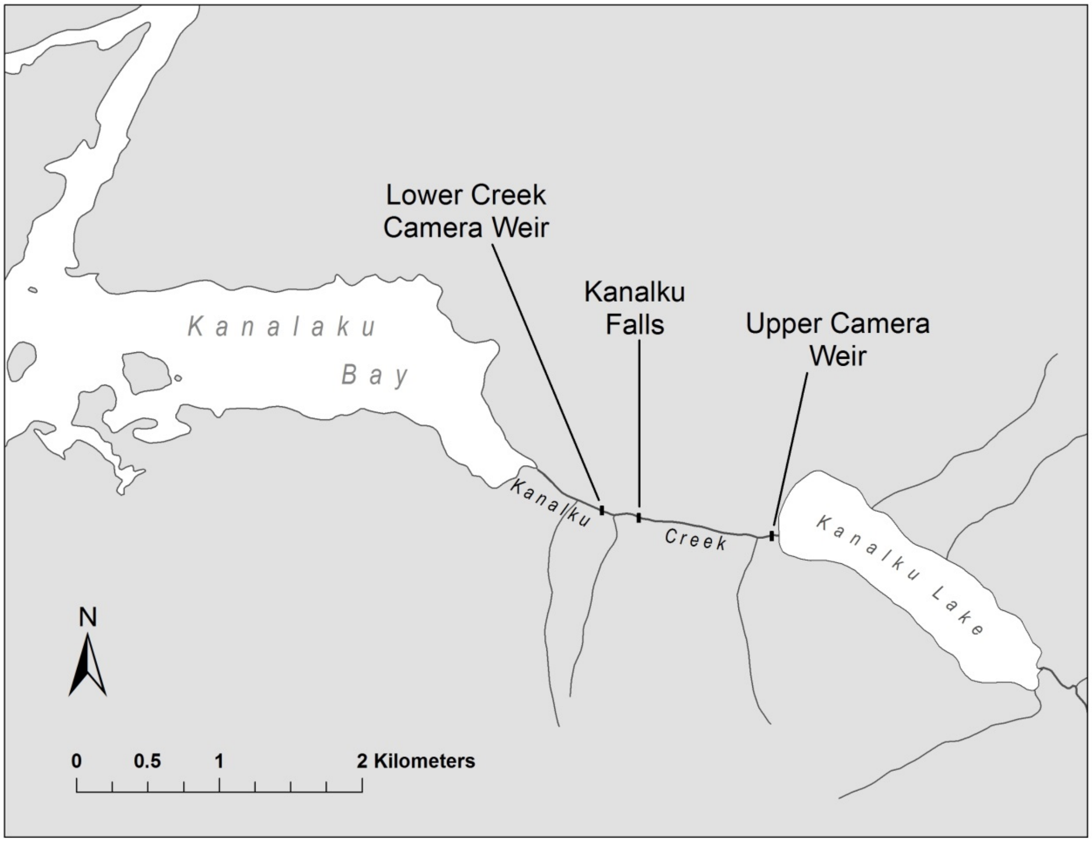

Figure 3.–Map of Kanalku Lake, Kanalku Falls, and location of the camera weirs.

SOCKEYE SALMON TOTAL ESCAPEMENT

The total sockeye salmon escapement into the Kanalku system was counted through a video camera weir located approximately 0.5 km upstream from the mouth of Kanalku Creek and approximately 300 m downstream of Kanalku Falls. Two video cameras were mounted to a video chute installed in the weir, and fish were recorded 24 hours per day (but primarily at night) as they swam by the underwater cameras (Figures 4–6). This method greatly reduced the incidence of fish holding behind the weir and eliminated the need to handle fish (Van Alen and Mahara 2011).

Lower Creek Camera Weir

The camera weir was constructed by anchoring aluminum bipods into the streambed with iron pipe. The bipods were connected by rows of 2.4 m-long aluminum channel stringers and panels of pickets that extended across the entire streambed. The weir was angled upstream to help guide fish quickly through the structure. A 2-camera video chute was attached to the weir face and secured to the streambed with iron pipe. The aluminum channel stringers were fitted with 0.75 m-tall, 1.3 cm-diameter EMT conduit pickets. Picket spacing was 4.4 cm on center of the pickets, allowing for 52 pickets per channel and a maximum space of approximately 3.81 cm between pickets (“pink salmon” spacing). Sandbags were used to seal the ends of the weir to the stream banks. Sandbags were also placed along the weir to hold down and secure the pickets to the streambed and to help reduce scouring under the weir. The weir was inspected daily for holes or scouring of the streambed. No problems have been experienced in the past with maintaining this weir, as Kanalku Creek is relatively small (only 18 m wide) and shallow (water depth at the weir site averages less than 45 cm at deepest location, and less than 30 cm over much of the length of the weir) at the weir site. The creek is not prone to dramatic flood events that are common in other drainages, and no problems with water clarity or turbidity have been experienced in the past.

Camera counts

Two underwater color video cameras containing Sony[1] 8.47 mm HAD CCD 3.6 mm sensors were installed on the video chute to record passing fish. Video cables transferred data from the cameras to mini-DVRs (Digital Video Recorders). The video was motion-detected, 30-frames-per-second, and video files were stored on SD memory cards. A 3-second “pre alarm” was used to record video prior to motion events in 2016 and 2017 to more easily count fast-moving fish (Vinzant and Heinl 2017). The video chute was lighted at night by two 25.4 cm, 14-bulb bright white LED light strips attached to the top of the chute. A photoelectric sensor was used to turn the lights on only from dusk to dawn to conserve battery power. The paired video system was powered by two 130-watt solar panels that trickle-charged a pair of 100 ah AGM (absorption glass matt) 12V DC batteries through metered 30A charge controllers. The mini-DVRs and a 17.78 cm color TFT monitor were housed onshore in a Pelican case (Figure 5). DC-DC step-down voltage converters were used to regulate power to the mini-DVRs (5V DC). For each camera in the video chute (left and right cameras), two SD cards were swapped back and forth daily.

The crew used a laptop computer to review video data at camp each day. Counts were conducted by hour for each camera and recorded daily on data sheets and in electronic files. Fish were identified and counted by species, and downstream migrants were noted and subtracted from totals. Since the total number of sockeye salmon will be relatively small (average annual count approximately 2,280 fish) all fish were directly counted; that is, there was no need to subsample video files and estimate numbers, as the counts provided a complete census of the number of fish that entered the Kanalku system. During the field season, video files were regularly spot-checked for accuracy to correct any problems. At the end of the season, all video files were reviewed at the Douglas ADF&G office to corroborate inseason counts. To date, there has been nearly complete agreement between the inseason and postseason counts. Identification of fish to species has not been a problem, as image quality of video footage captured with the camera equipment is generally very good (Figure 6).

[1] Product names that appear in this report are included for completeness and do not reflect an endorsement by the Alaska Department of Fish and Game.

Figure 4.–Camera weir installed in lower Kanalku Creek, below Kanalku Falls, 2017. (©2017 ADF&G/photo by Raymond F. Vinzant.)

Figure 5.–Camera weir video recording components housed in a waterproof Pelican case. (©2016 ADF&G/photo by Raymond F. Vinzant.)

Figure 6.–Sockeye salmon swimming through the video chute in the lower creek camera weir. (©2013 ADF&G/photo by Raymond F. Vinzant.)

SOCKEYE SALMON SPAWNING ESCAPEMENT

In previous seasons we used a standard picket weir in combination with a mark–recapture study to estimate the spawning population of sockeye salmon at Kanalku Lake. From 2013 to 2015 we installed an additional camera weir upstream of the standard picket weir to provide a second count to validate the picket weir count. In all three seasons, however, we observed frequent predation on sockeye salmon by river otters (*Lontra canadensis*) between the two weir structures (Vinzant and Heinl 2014, 2015a, and 2016). As a result, we removed the standard picket weir mid-season in 2015 and used only the camera weir to count the spawning escapement of sockeye salmon into Kanalku Lake (Vinzant and Heinl 2016). In 2016 we simplified the operation by installing a single double-fence weir with a camera chute incorporated in the center—a design very similar to the "double-redundant" weir used at Neva Lake (Van Alen and Musslewhite 2015) except that we used only one video chute instead of two. This weir system worked at Kanalku, because the outlet stream is relatively small and shallow and not prone to severe flood events; it provided a complete census of the spawning population while allowing fish to swim unimpeded through the weir 24 hours per day, eliminated the need to validate the weir count with a mark–recapture study, and virtually eliminated predation at the weir site (Vinzant and Heinl 2017).

Lake Camera Weir count

The camera weir was located in Kanalku Creek, directly below the outflow of Kanalku Lake. The primary weir fence was constructed from the standard picket weir used in previous seasons and consisted of aluminum bipod supports anchored to the streambed. The bipods were connected by rows of 2.4 m-long aluminum channel stringers and panels of pickets that extended the width of the stream. Pickets (300 cm, EMT conduit) were inserted through the aluminum stringers and extended to the streambed. Picket spacing was 4.4 cm on center of the pickets, allowing for 52 pickets per channel and a maximum space of approximately 3.81 cm between pickets ("pink salmon" spacing). Stream depth was measured daily at the weir site in approximately the same location (within 1 m^2) as the 2007 to 2013 field seasons.

To ensure the weir was fish tight and no sockeye salmon could pass through it undetected, we installed a secondary picket fence directly upstream and within 1 m distance of the primary weir structure. The secondary picket fence also consisted of 52-hole aluminum channel stringers and panels of pickets that were anchored to the streambed with iron pipe and braced back to the primary weir structure (Figure 7). The pickets were approximately 100 cm long and extended to the streambed. A small fish trap (125 × 245 cm) was connected to the upstream side of the secondary fence (Figure 8). A 2-camera video chute was installed in the center of the weir to count fish as they travelled through the weir structure. The chute was approximately 125 cm long and spanned both the primary and secondary weir fences to allow fish to swim through both weirs unimpeded. A "V" shaped entrance was used to guide fish into the chute. Sandbags were used to seal the ends of the weirs to the stream banks. Sandbags were also placed along the lengths of both weir fences to help stabilize the substrate and secure the pickets in place.

If a sockeye salmon slipped through a hole or gap in the primary weir fence it would be trapped between the two fences or captured in the fish trap, either of which would indicate a breach in the primary weir fence. The field crew would immediately assess the weir structure and locate and fix the breach. The weir was inspected daily for breaches or malfunctions. Fish were recorded 24 hours per day using the exact same camera and electronic equipment described above for the lower creek camera weir. Inseason and postseason review of video files and recording of data also followed methods described for the lower creek camera weir.

Figure 7.–Double-fence camera weir, Kanalku Lake, 2016. (©2016 ADF&G/photo by Steven C. Heinl.)

Figure 8.–Double-fence camera weir showing upstream trap, Kanalku Lake, 2016. (©2016 ADF&G/photo by Raymond F. Vinzant.)

Estimate of Mortality Rate at Kanalku Falls

The mortality rate at the Kanalku Falls (i.e., the number of fish that did not successfully ascend the falls) was estimated by simply subtracting the spawning escapement (the number of fish counted into the lake) from the total sockeye salmon escapement (the number of fish counted into the Kanalku Creek system below Kanalku Falls).

Adult Population Age and Size Composition

Based on work by Thompson (1987), scale samples from 230 sockeye salmon would ensure estimated proportions of each age class would be within 5% of the true value with at least 90% probability, based on two age classes (age-1.2 and age-1.3 fish account for an average 96% of the escapement; Appendix C) and a spawning population of 1,500 fish. Scale samples were to be collected from live fish captured with a beach seine on the spawning grounds in Kanalku Lake beginning in late August following protocols outlined in Vinzant and Heinl (2015b); however, sampling was not conducted due to the very small spawning escapement in 2017 (see Results below).

RESULTS

Sockeye Salmon Total Escapement Estimate

The camera weir on lower Kanalku Creek, downstream of Kanalku Falls, was operated between 22 June and 28 August, 2017. Sockeye salmon were first recorded swimming through the weir on 28 June. A total of 870 adult sockeye salmon were counted through the lower creek camera weir, and the largest daily count of 117 sockeye salmon was observed on 30 July (Figure 9;

Appendix B). No jack sockeye salmon (fish <400 mm in length) were observed in the video files. Sockeye salmon moved through the weir primarily at night between 23:00 and 04:00.

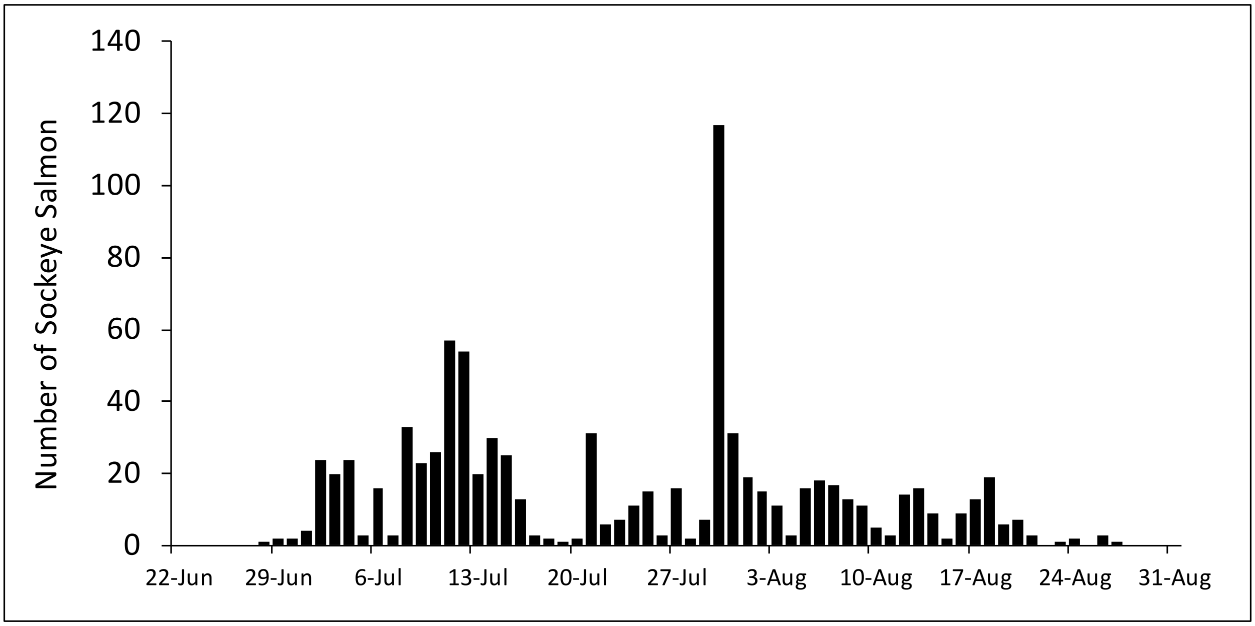

Figure 9.–Daily sockeye salmon counts at the lower Kanalku Creek camera weir, below Kanalku Falls, 2017.

The camera weir was operated without problem for the duration of the sockeye salmon migration. No serious high water events occurred, and no holes or gaps were found on the weir face that would have allowed fish to swim through undetected. During installation, efforts were made to deepen the streambed under and around the video chute by approximately 30 cm. The slightly deeper channel and reduced current seemed effective in encouraging sockeye salmon to swim more slowly through the chute, which greatly reduced the number of video files of partial fish compared to previous seasons. Sockeye salmon were easily identified by the field crew while reviewing the video files, and a post-season review of all video files resulted in a difference of only four fish.

Other species of fish recorded at the camera weir included pink salmon, abundant Dolly Varden and cutthroat trout, and several chum salmon. We did not enumerate fish species other than sockeye salmon because we considered those counts to be incomplete. Pink and chum salmon primarily spawn downstream of the weir, and smaller cutthroat trout and Dolly Varden are able to swim through the weir fence and bypass the video cameras entirely.

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

Lake Camera Weir Count

The lake camera weir was installed on 22 June and operated until 31 August. The first sockeye salmon was recorded on 1 July, three days after the first sockeye salmon was observed at the lower creek weir downstream of Kanalku Falls. A total of 468 adult sockeye salmon were counted through the lake camera weir and the largest daily count of 67 sockeye salmon occurred on 31 July (Figure 10; Appendix B). No jack sockeye salmon or other species of salmon were observed at the lake camera weir. Periods of high water occurred during approximately 2–6 July and 15–21 August. The primary weir was judged to have been "fish tight" for the entire season, as no fish were caught between the weir or in the secondary weir trap, which would have indicated a hole or breach in the primary weir. The spawning escapement count of 468 adult sockeye salmon was 54% of the total escapement of 870 sockeye salmon counted into Kanalku Creek below Kanalku Falls—an inriver mortality rate of 46%.

ADULT POPULATION AGE AND SIZE COMPOSITION

We did not meet Objective 4 to estimate the age, sex, and length composition of the sockeye salmon escapement in 2017. Due to the small sockeye salmon spawning population (only 468 fish), we cancelled sampling that was scheduled for late August–September rather than disturb spawning activity and subject the fish to the stress of capture and handling.

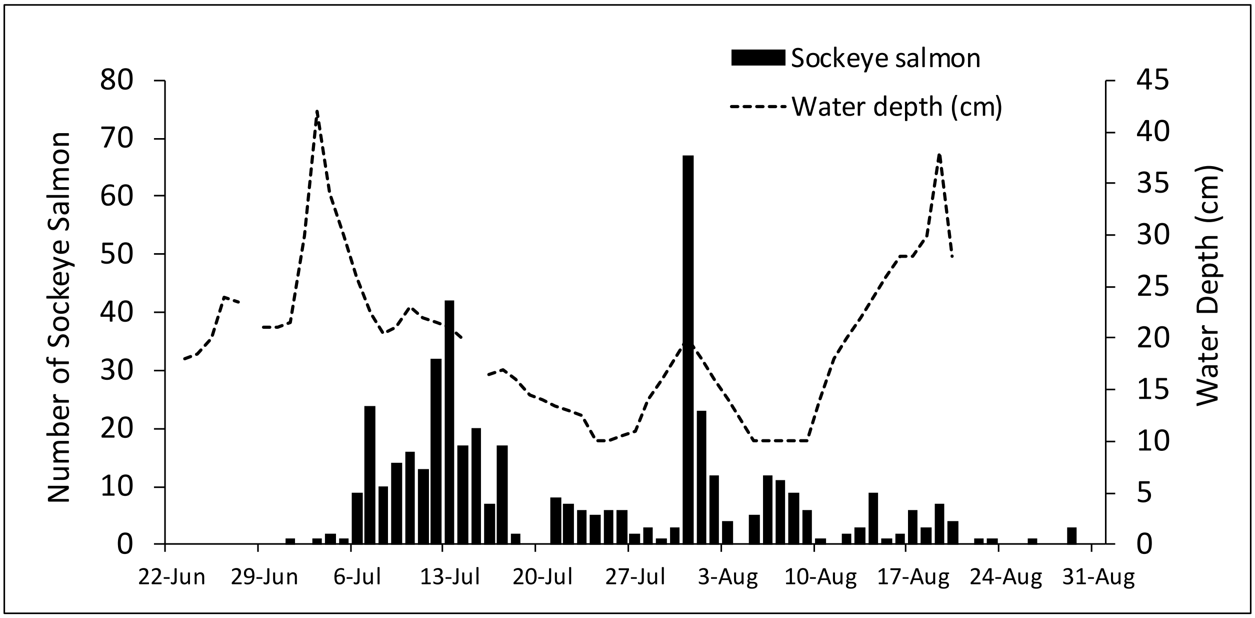

Figure 10.–Daily sockeye salmon counts and water depth (cm) at the lake camera weir, Kanalku Lake, 2017.

DISCUSSION

The total escapement of 870 sockeye salmon counted into the Kanalku system, downstream of Kanalku Falls, was approximately 38% of the 2012–2016 average of 2,280 fish. The spawning escapement, counted at the outlet of Kanalku Lake, was 468 sockeye salmon; thus, we estimate that only 54% of the inriver run successfully ascended the falls in 2017, an inriver mortality rate of 46%. The spawning escapement was the smallest observed since weir operations began in 2007, the third smallest since stock assessment studies were initiated in 2001, and approximately 35% of the 2001–2016 average spawning escapement of 1,320 fish (Figure 11; Appendix A). Prior to 2017, our hypothesis was that stream depth is negatively correlated with passage of sockeye salmon at Kanalku Falls: high average stream depth in 2012 resulted in the lowest passage rate (49%) and relatively low average stream depth in 2013 resulted in the highest passage rate (76%) (Figure 12). In 2017, however, stream depth during the period of peak sockeye salmon movement into the creek (late July–early August) was relatively low (Figure 13), yet the passage rate (54%) was the second lowest since 2012 and the lowest since the barrier modification work was completed at the falls (Figure 12).

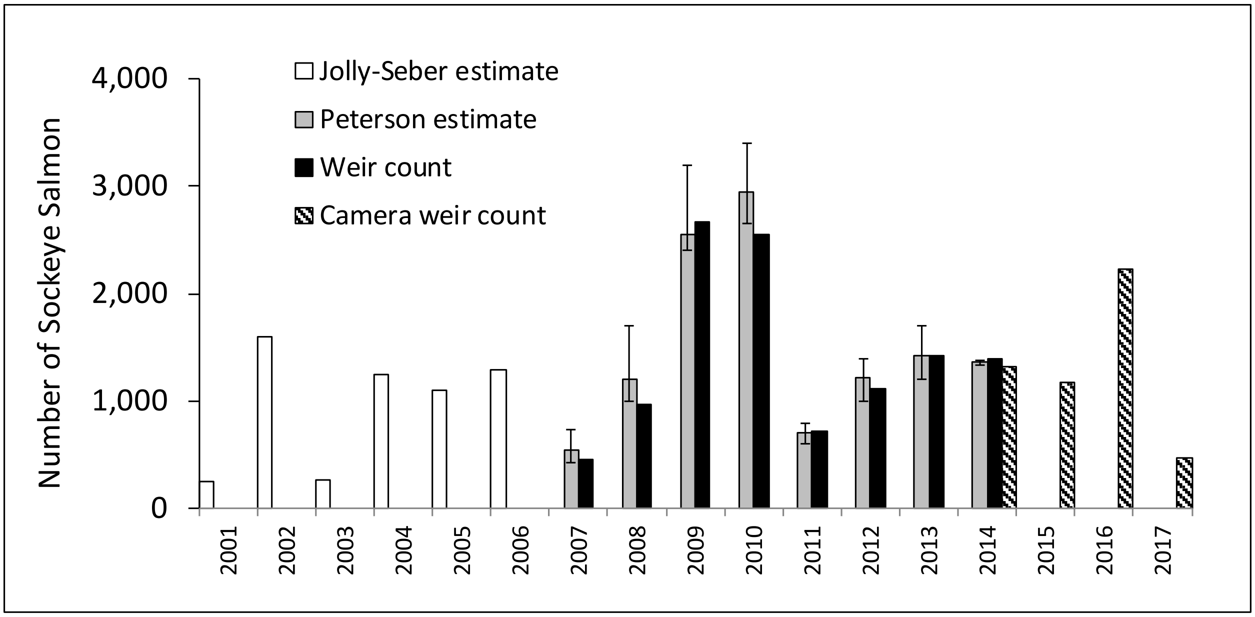

Figure 11.–Estimated sockeye salmon spawning escapements at Kanalku Lake, 2001–2017. Error bars represent the 95% confidence intervals of the Petersen mark–recapture estimates.

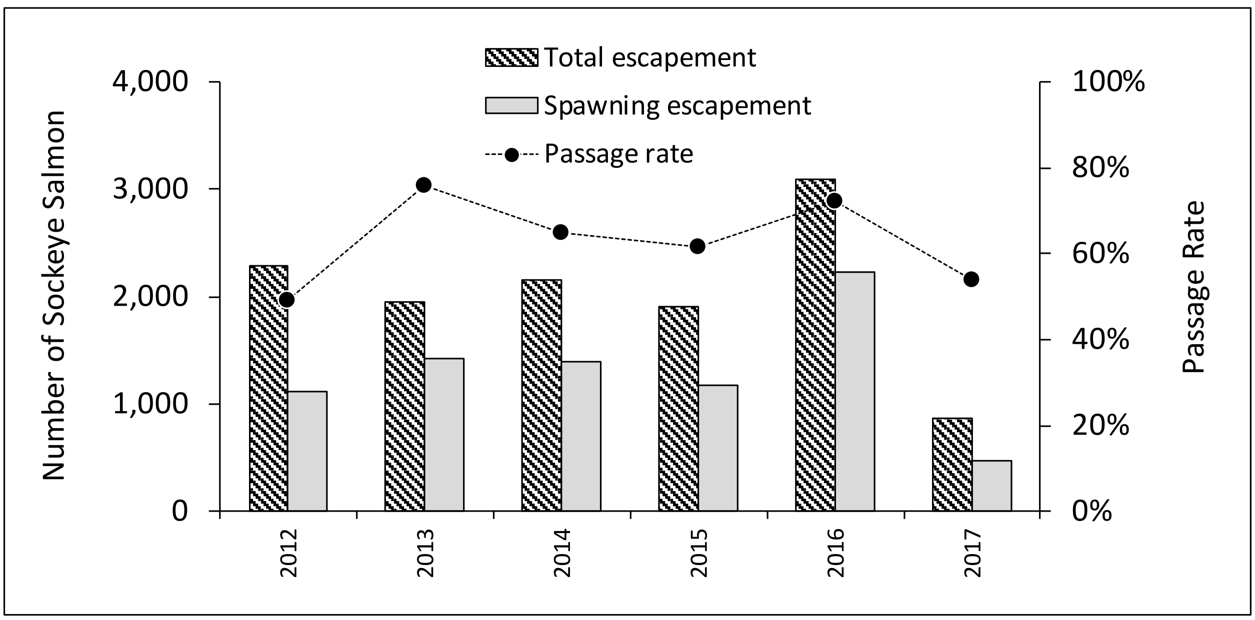

Figure 12.–Total escapement into the Kanalku system below Kanalku Falls, spawning escapement at Kanalku Lake, and inriver passage rate, 2012–2017. The falls were modified to improve fish passage following the 2013 season.

The objective of Phase I of the barrier modification work conducted in August 2013 was to improve sockeye salmon passage such that 80% or more of the fish successfully navigate the falls (USDAFS 2011); however, passage rates do not appear to have changed substantially. From 2014 to 2017, passage rates averaged 63% and ranged from 54% (2017) to 72% (2016), very similar to the passage rates observed before the barrier work was completed (Figure 12). Comparison of daily sockeye salmon counts above and below the falls showed that pulses of sockeye salmon into the system below the falls were often followed 1–5 days later by peaks of smaller numbers of sockeye salmon at the lake (Appendices D–I). Sockeye salmon would presumably swim directly from saltwater to the lake in one night if passage was not impeded at the falls. Instead, sockeye salmon stage in the pools below the falls, where they are vulnerable to predation from river otters and brown bears (*Ursus arctos Linnaeus*) and occasionally to subsistence harvest. Further modification of the falls would be required to increase passage rates to 80% or more of the inriver run. Phase II of the barrier modification plan would be to construct a 45–60 cm high concrete sill around the downstream side of the plunge pool to increase the height, depth, and size of the pool to shorten the distance and height fish must jump to clear the falls (USDAFS 2011).

The Kanalku Lake sockeye salmon run has been limited by very small spawning escapements that have produced modest numbers of adult recruits 4–5 years later. The 2017 spawning escapement of only 468 fish is likely to produce very small returns of age-4 fish (age 1.2, the dominant age at return; Appendix C) in 2021 and age-5 fish in 2022. Rough run reconstruction suggests that returns from brood years 2001–2012 averaged 2.3 fish per spawner (range 0.9–4.1 fish per spawner) (Figure 14; Appendix J). True recruit per spawner values for Kanalku Lake are certainly larger than the minimum values presented here due to lack of commercial harvest estimates, under-reporting of subsistence harvests, and lack of mortality rate estimates at the falls prior to 2012; however, the true values are probably within the average range of 1.7–3.7 recruits per spawner estimated for other Southeast Alaska sockeye salmon populations (Geiger 2003; Eggers and Bernard 2011; Heinl et al. 2014; Brenner et al. 2018; Miller and Heinl *in press*). As a result, the number of sockeye salmon that spawn at Kanalku Lake will need to increase substantially above the low levels observed over the past 18 years if annual runs are expected to improve.

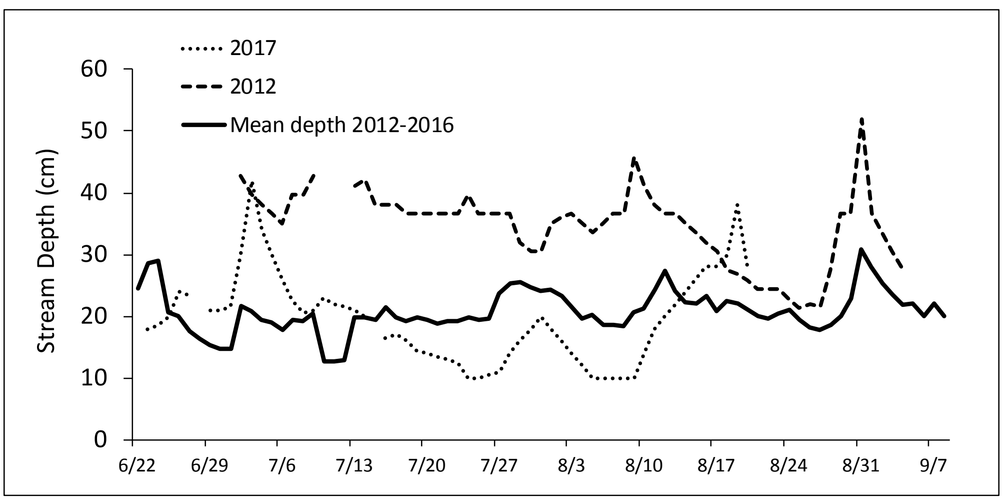

Figure 13.–Daily Kanalku Creek stream depth (cm) measured at the outlet of Kanalku Lake in 2017 compared to the high-water year of 2012 and to the mean stream depth from 2012 to 2016.

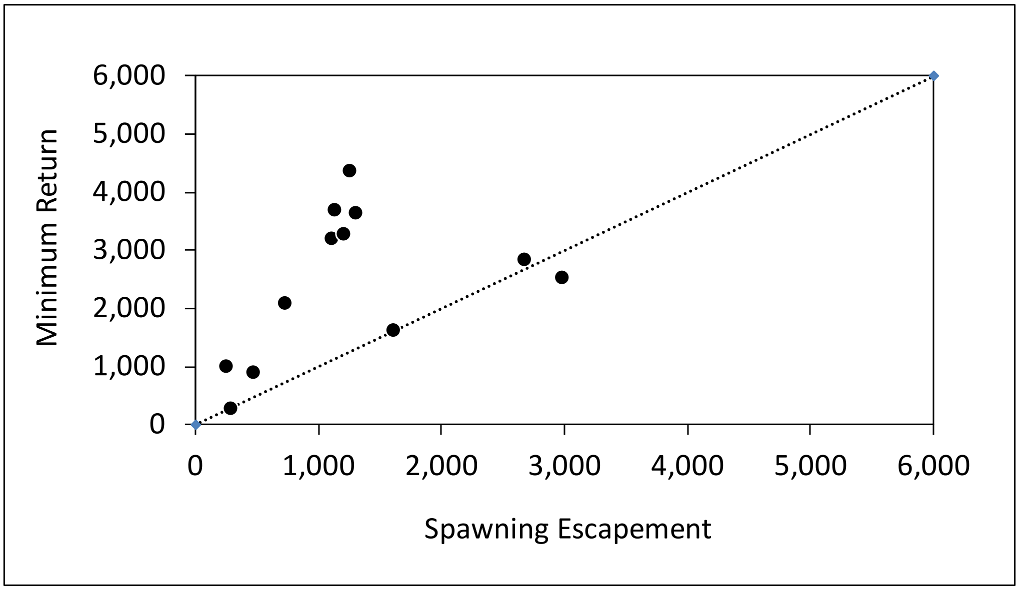

Figure 14.–Minimum estimated returns per spawner for Kanalku Lake sockeye salmon brood years 2001–2012. The dotted line represents the one-to-one line.

Video camera and DVR systems used at Kanalku starting in 2012 proved very reliable and few problems were experienced throughout the lifespan of the project. Solar power was usually sufficient to keep the systems operating 24 hours per day, though extended periods of low cloud cover occasionally required use of a small generator to recharge the battery banks. Low light conditions resulted in poorer quality (grainy) video images when the camera chute lights were not on; however, fish could still be accurately identified and counted. Possibly the biggest challenge was dealing with unnecessary triggering of the DVRs by debris, small trout and char that lingered around the camera chute, and glare from sunlight, all of which frequently resulted in extra time needed to review video data files.

The double-fence weir used to count the sockeye salmon spawning escapement at the outlet of Kanalku Lake in 2016 and 2017 greatly simplified the project and provided several advantages over methods used in previous years. It eliminated the need to validate weir counts with mark–recapture studies that require trapping and handling of fish and add logistical complexity and uncertainty to the project (Vinzant et al. 2012). Sockeye salmon were instead allowed to migrate upstream unimpeded by the weir 24 hours per day, which virtually eliminated the incidence of fish holding behind the weir (sockeye salmon migrate upstream at Kanalku primarily at night) and greatly minimized predation observed at the weir site in previous years (Vinzant and Heinl 2014, 2015a, and 2016). Finally, the use of one camera chute, rather than the two required for operating two separate weirs to validate weir counts ("double-redundant" weir system; Van Alen and Mahara 2011), greatly reduced both the equipment and electrical components needed and the time required to review video files.

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APPENDICES

Appendix A.–Estimated annual spawning escapement and subsistence harvest of Kanalku Lake sockeye salmon, 2001–2017. Escapement estimates were based on weir counts and mark–recapture estimates.

			Mark–Recapture Estimate				Final	
Year	Weir Count	Camera-Weir Count	Petersen Estimate[a]	Jolly-Seber Estimate[b]	95% CI	Expanded Jolly-Seber[b]	Escapement Estimate	Subsistence Harvest[c]
2001	–	–	–	250	130–380	250	250	951
2002	–	–	–	1,300	1,200–1,400	1,600	1,600	14
2003	–	–	–	280	250–300	280	280	90
2004	–	–	–	820	750–900	1,250	1,250	60
2005	–	–	–	950	900–1,000	1,100	1,100	50
2006	–	–	–	1,100	1,000–1,200	1,300	1,300	51
2007	461	–	576	–	430–740	–	461	10
2008	967	–	1,200	–	1,000–1,500	–	1,200	723
2009	2,664	–	2,750	–	2,500–3,200	–	2,664	600
2010	2,555	–	2,970	–	2,660–3,380	–	2,970	543
2011	728	–	690	–	600–800	–	728	434
2012	1,123	–	1,215	–	1,000–1,400	–	1,123	826
2013	1,427	–	1,440	–	1,220–1,690	–	1,427	569
2014	1,398	1,321	1,360	–	1,330–1,375	–	1,360	745
2015	–	1,180	–	–	–	–	1,180	245
2016	–	2,236	–	–	–	–	2,236	652
2017	–	468	–	–	–	–	468	240

[a] Chapman's modified Petersen estimate.

[b] Jolly-Seber estimates from 2001 to 2006 were expanded based on the ratio of the number sockeye salmon observed in the mark–recapture study area to the number observed in the entire lake (see Conitz and Burril 2008).

[c] Subsistence harvest was reported from returned ADF&G subsistence salmon fishing permits. A voluntary subsistence closure was in place from 2002 to 2005.

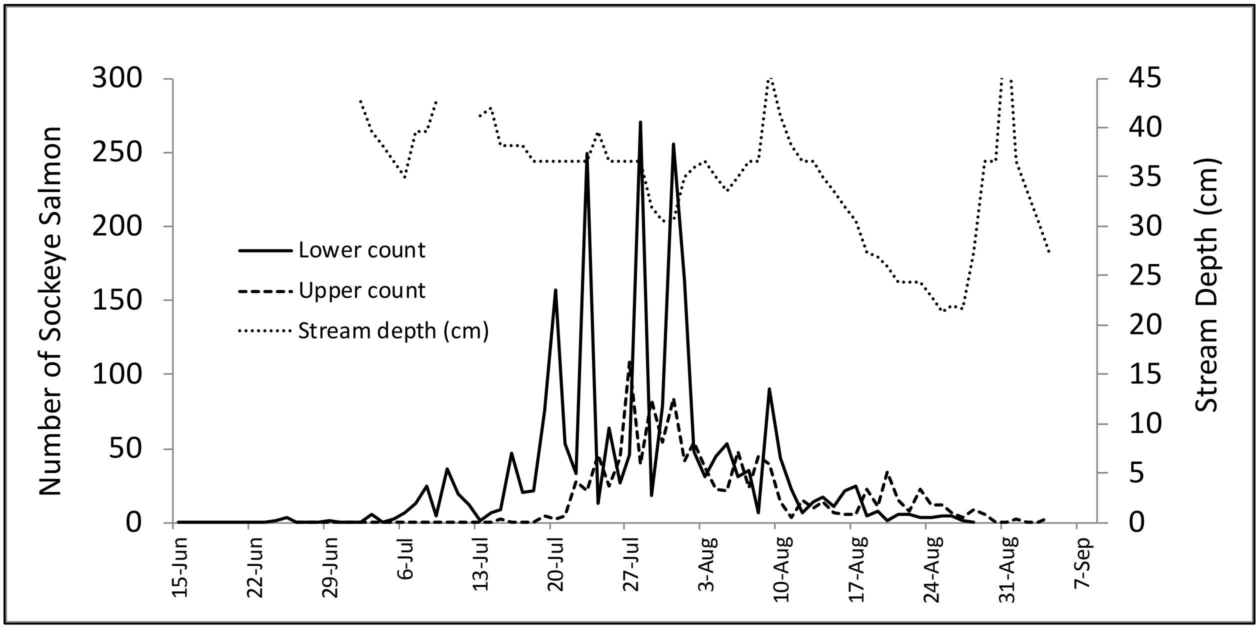
Appendix B.–Daily counts of sockeye salmon below Kanalku Falls (lower weir) and at Kanalku Lake (lake weir), and daily stream depth measured at the outlet of Kanalku Lake, 2017. Other fish species were not enumerated and the lower weir, and only sockeye salmon were observed at the lake weir.

	Sockeye Salmon Counts				Sockeye Salmon Counts		
Date	Lower Weir	Lake Weir	Stream Depth (cm)	Date	Lower Weir	Lake Weir	Stream Depth (cm)
22-Jun	0	0	—	28-Jul	2	3	14.0
23-Jun	0	0	18.0	29-Jul	7	1	16.0
24-Jun	0	0	18.5	30-Jul	117	3	18.0
25-Jun	0	0	20.0	31-Jul	31	67	20.0
26-Jun	0	0	24.0	1-Aug	19	23	18.0
27-Jun	0	0	23.5	2-Aug	15	12	16.0
28-Jun	1	0	—	3-Aug	11	4	14.0
29-Jun	2	0	21.0	4-Aug	3	0	12.0
30-Jun	2	0	21.0	5-Aug	16	5	10.0
1-Jul	4	1	21.5	6-Aug	18	12	10.0
2-Jul	24	0	30.0	7-Aug	17	11	10.0
3-Jul	20	1	42.0	8-Aug	13	9	10.0
4-Jul	24	2	34.0	9-Aug	11	6	10.0
5-Jul	3	1	30.0	10-Aug	5	1	14.0
6-Jul	16	9	26.0	11-Aug	3	0	18.0
7-Jul	3	24	22.5	12-Aug	14	2	20.0
8-Jul	33	10	20.5	13-Aug	16	3	22.0
9-Jul	23	14	21.0	14-Aug	9	9	24.0
10-Jul	26	16	23.0	15-Aug	2	1	26.0
11-Jul	57	13	22.0	16-Aug	9	2	28.0
12-Jul	54	32	21.5	17-Aug	13	6	28.0
13-Jul	20	42	21.0	18-Aug	19	3	30.0
14-Jul	30	17	20.0	19-Aug	6	7	38.0
15-Jul	25	20	—	20-Aug	7	4	28.0
16-Jul	13	7	16.5	21-Aug	3	0	—
17-Jul	3	17	17.0	22-Aug	0	1	—
18-Jul	2	2	16.0	23-Aug	1	1	—
19-Jul	1	0	14.5	24-Aug	2	0	—
20-Jul	2	0	14.0	25-Aug	0	0	—
21-Jul	31	8	13.5	26-Aug	3	1	—
22-Jul	6	7	13.0	27-Aug	1	0	—
23-Jul	7	6	12.5	28-Aug	0	0	—
24-Jul	11	5	10.0	29-Aug	—	3	—
25-Jul	15	6	10.0	30-Aug	—	0	—
26-Jul	3	6	10.5	31-Aug	—	0	—
27-Jul	16	2	11.0	Total	870	468	

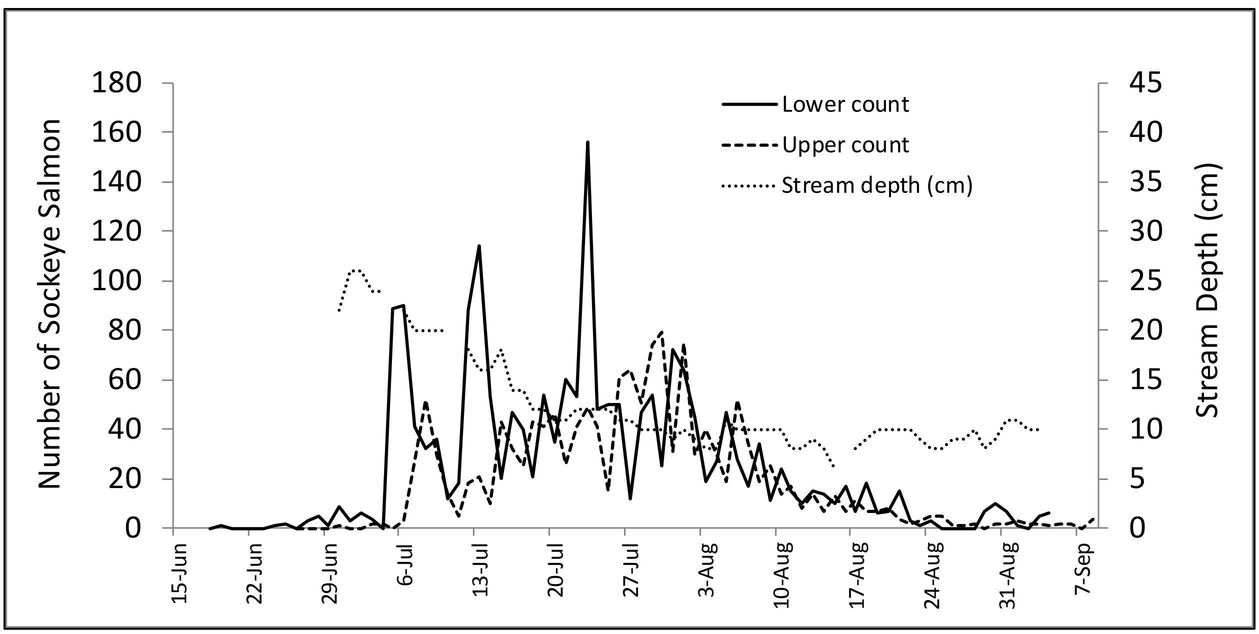
Appendix C.–Age composition of sockeye salmon spawning escapements at Kanalku Lake, 2001–2015. Age composition from 2007 to 2014 was based on weighted weekly escapement counts at the Kanalku Lake weir; age composition in other years was based on unweighted samples collected on the spawning grounds. Age composition was not estimated in 2016 and 2017.

	Age Class						
Year	1.1	1.2	1.3	2.1	2.2	2.3	3.2
2001	0.000	0.551	0.427	0.000	0.022	0.000	0.000
2002	0.000	0.803	0.164	0.000	0.033	0.000	0.000
2003	0.000	0.873	0.115	0.000	0.013	0.000	0.000
2004	0.000	0.760	0.228	0.000	0.012	0.000	0.000
2005	0.003	0.847	0.111	0.008	0.029	0.003	0.000
2006	0.000	0.968	0.032	0.000	0.000	0.000	0.000
2007	0.000	0.330	0.594	0.000	0.063	0.013	0.000
2008	0.000	0.956	0.015	0.000	0.026	0.003	0.000
2009	0.000	0.660	0.278	0.000	0.062	0.000	0.000
2010	0.000	0.870	0.123	0.000	0.006	0.002	0.000
2011	0.000	0.494	0.460	0.000	0.041	0.005	0.000
2012	0.000	0.885	0.066	0.000	0.044	0.000	0.005
2013	0.000	0.798	0.145	0.000	0.031	0.002	0.024
2014	0.000	0.770	0.202	0.000	0.027	0.000	0.001
2015	0.005	0.841	0.101	0.000	0.048	0.005	0.000
Mean	0.000	0.760	0.204	0.001	0.031	0.002	0.002

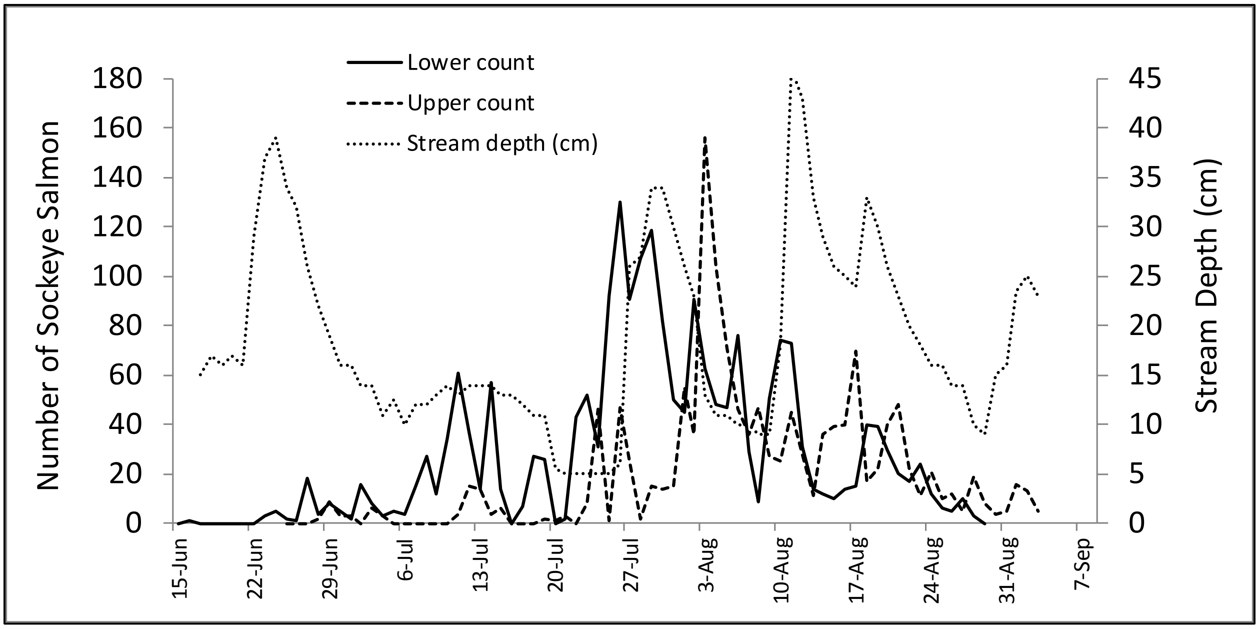
Appendix D.–Daily sockeye salmon counts below (lower count) and above (upper count) Kanalku Falls, and daily stream depth (cm) measured at the outlet of Kanalku Lake, 2012.



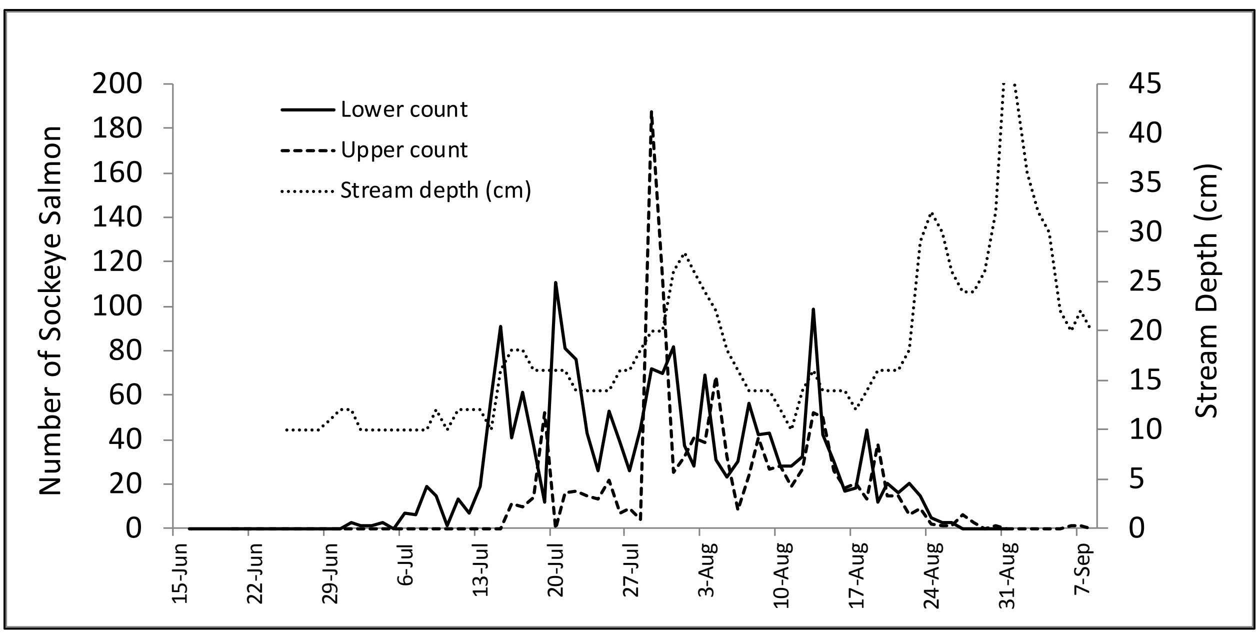
Appendix E.–Daily sockeye salmon counts below (lower count) and above (upper count) Kanalku Falls, and daily stream depth (cm) measured at the outlet of Kanalku Lake, 2013.



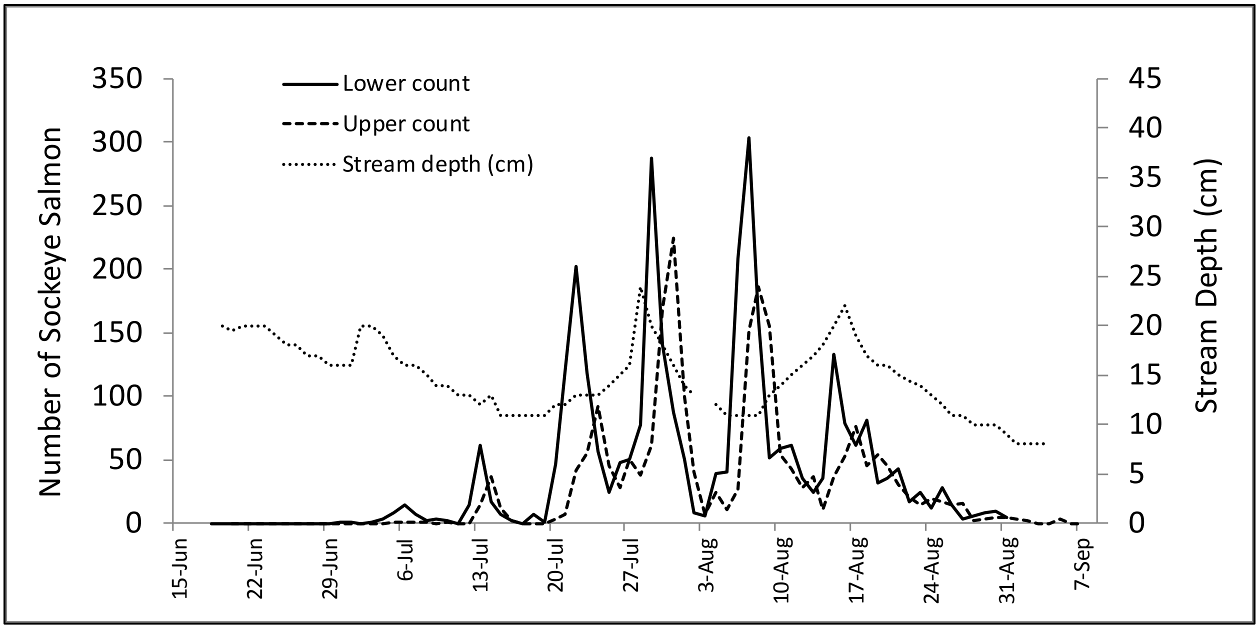
Appendix F.–Daily sockeye salmon counts below (lower count) and above (upper count) Kanalku Falls, and daily stream depth (cm) measured at the outlet of Kanalku Lake, 2014.



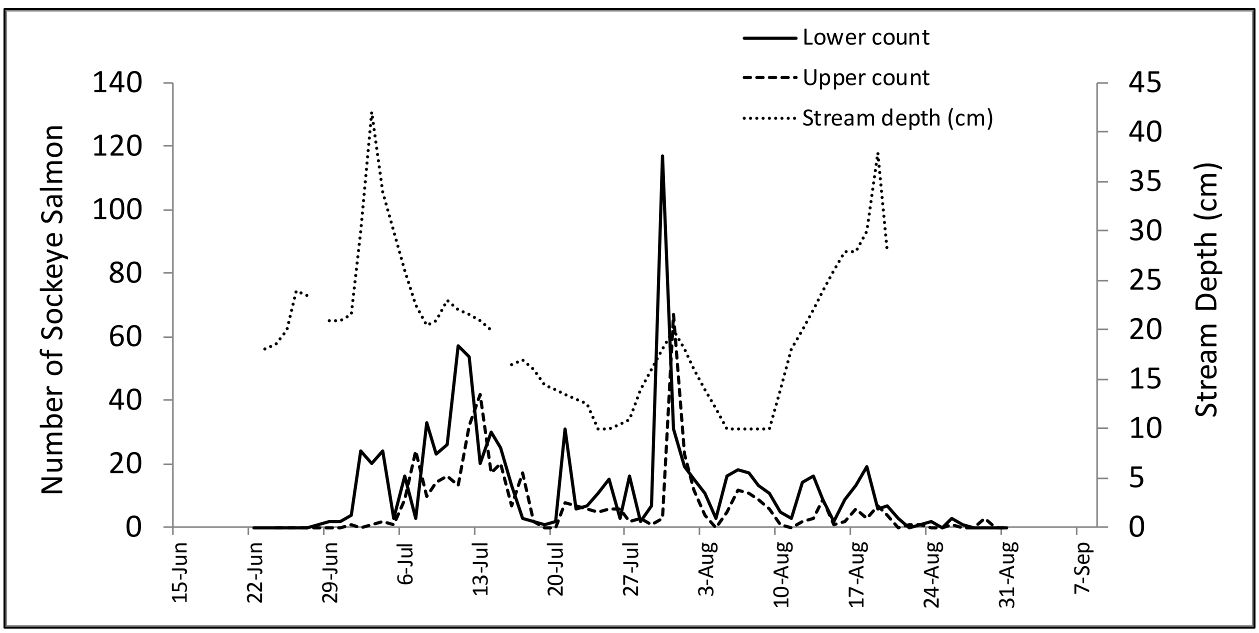
Appendix G.–Daily sockeye salmon counts below (lower count) and above (upper count) Kanalku Falls, and daily stream depth (cm) measured at the outlet of Kanalku Lake, 2015.



Appendix H.–Daily sockeye salmon counts below (lower count) and above (upper count) Kanalku Falls, and daily stream depth (cm) measured at the outlet of Kanalku Lake, 2016.



Appendix I.–Daily sockeye salmon counts below (lower count) and above (upper count) Kanalku Falls, and daily stream depth (cm) measured at the outlet of Kanalku Lake, 2017.



Appendix J.–Run reconstruction of Kanalku Lake sockeye salmon and minimum return per spawner for brood years 2001–2012.

Run Year	Harvest: Comm.[a]	Harvest: Subs.[b]	Inriver Mortality[c]	Spawning Escapement	Total Run	Escapement Age Comp[d]: Age 4	Escapement Age Comp[d]: Age 5+	Return by Age and Year: Year	Return by Age and Year: Age 4	Return by Age and Year: Year	Return by Age and Year: Age 5+	Total Return	Return per Spawner
2001	*ND*	951	*ND*	250	1,201	55%	45%	2005	983	2006	43	1,026	4.1
2002	*ND*	14	*ND*	1,600	1,614	80%	20%	2006	1,308	2007	316	1,623	1.0
2003	*ND*	90	*ND*	280	370	87%	13%	2007	155	2008	137	293	1.0
2004	*ND*	60	*ND*	1,250	1,310	76%	24%	2008	2,986	2009	1,412	4,397	3.5
2005	*ND*	50	*ND*	1,100	1,150	86%	14%	2009	2,740	2010	460	3,201	2.9
2006	*ND*	51	*ND*	1,300	1,351	97%	3%	2010	3,056	2011	588	3,644	2.8
2007	*ND*	10	*ND*	461	471	33%	67%	2011	574	2012	360	934	2.0
2008	*ND*	723	1,200	1,200	3,123	96%	4%	2012	2,768	2013	557	3,324	2.8
2009	*ND*	600	888	2,664	4,152	66%	34%	2013	2,200	2014	668	2,868	1.1
2010	*ND*	543	*ND*	2,970	3,513	87%	13%	2014	2,236	2015	332	2,568	0.9
2011	*ND*	434	*ND*	728	1,162	49%	51%	2015	1,813	2016	300	2,113	2.9
2012	12	826	1,166	1,123	3,127	88%	12%	2016	3,445	2017	254	3,700	3.3
2013	250	569	511	1,427	2,757	80%	20%	2017	856	2018	—	—	—
2014	11	745	750	1,398	2,904	77%	23%	2018	—	2019	—	—	—
2015	*ND*	245	731	1,180	2,156	84%	15%	2019	—	2020	—	—	—
2016	*ND*	652	857	2,236	3,745	92%	8%	2020	—	2021	—	—	—
2017	*ND*	240	402	468	1,110	77%	23%	2021	—	2022	—	—	—

Note: ND = no data available.

[a] Commercial harvest estimates based on genetic stock identification are available only for purse seine fisheries in Icy and upper Chatham straits 2012–2014 and only for fisheries that were sampled in those years (data from Gilk Baumer et al. 2015).

[b] Subsistence harvests are reported on returned ADF&G subsistence harvest permits, which under-represent the true harvest (Walker 2009).

[c] Inriver mortality is the number of sockeye salmon counted below Kanalku Falls minus the spawning escapement; data not available for 2001–2007 and 2010–2011.

[d] Age composition of the spawning escapement not available for 2016–2017; age composition for 2016 was estimated to be at least 92% age 1.2 fish (Vinzant and Heinl 2017); age composition for 2017 was assumed to be equal to the 2001–2015 average (Appendix C).